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The Triassic system of Thailand: implication on geotectonic evolution of Southeast Asia

CHONGPAN CHONGLAKMANI

School of Geotechnology
Suranaree University of Technology
Nakhon Ratchasima
Thailand

Abstract: Plate tectonic reconstructions of Southeast Asia is quite complicated as the areas are composed of several terranes accreted by complex processes of subduction, collision and transform faulting. Four main Triassic sedimentary facies can be distinguished, viz. the continental facies, the continental platform facies, the marine intra-arc facies, and the deep marine and oceanic facies. The continental facies characterized by alluvial fan, fluvial and lacustrine sequence (Huai Hin Lat and Kuchinarai Formations) represents the sediments of retroarc foreland basins covering the areas of northeastern Thailand (amalgamated Indosinia and Sukhothai terranes). The continental platform facies consists of shallow marine shelf clastics and carbonates distributed in the "Shan-Mergui" (Lower Mae Moei and Si Sawat Groups) and the Chiang Mai (Phrao Limestone, Klaeng Limestone) terranes. The marine intra-arc facies (Lampang and Phrae Groups, Nam Pat and Pong Nam Ron Formations) is distributed extensively within a volcanoplutonic setting on the western part of amalgamated Sukhothai-Indosinia terranes. It consists of shallow water siliciclastics and carbonates, the deeper water turbidites and its associated rhyolitic and andesitic volcanics. The deep marine and oceanic facies consist of radiolarian chert, pelagic limestone, turbidite and basalts distributed in two zones representing two distinct Triassic sutures in these areas. One is the Chiangrai-Chanthburi belt which extends southward into the Bentong-Raub suture of Malaysia. The other is Mae Sariang-Kanchanaburi belt and it extends southward to western Malaysia and central Sumatra. The distribution of the Permian and Triassic sequences and its tectonic setting indicate that Thailand and adjacent territories is a complex orogenic collage. The famous and well-known Nan-Uttaradit-Sra Kaeo ophiolite belt previously considered as representing a Late Triassic suture is a Late Permian one. The major terrane accretions are in the Late Triassic by the processes of subduction to the east in the Late Carnian and the Middle to Late Norian respectively.

INTRODUCTION

The Triassic sedimentary sequences are distributed extensively in Thailand. They are predominantly marine except in the northeast they are inclusively continental. The distribution and the stratigraphic nomenclature of these sequences are shown and summarized in Figure 1 and Table 1. The stratigraphy and its biostratigraphic subdivision of the marine Triassic sequences were discussed in detail by Chonglakmani and Grant-Mackie (1993).

The geotectonic evolution of Thailand and her adjacent terriories has been proposed and discussed by many workers (Bunopas, 1982; Chonglakmani and Helmcke, 1989; Hutchison, 1989; Carey *et al.*, 1995). The previous proposed models are varied and inconsistent because of the disagreement on suture identification, correlation of various suture belts, and closing time of remnant occans. Parts of the confusion are also from its complex geology and mis-interpretation of the marine Triassic sediments. Detailed study of the Triassic stratigraphy, paleontology and sedimentology including its related volcanism, magmatism and structural development is critical for understanding the geotectonic evolution and imposing constraint on the proposed models.

THE SEDIMENTARY FACIES

Four distinct Triassic sedimentary facies can be distinguished in Thailand. These are the continental facies, the continental platform facies, the marine intra-arc facies, and the deep marine and oceanic facies.

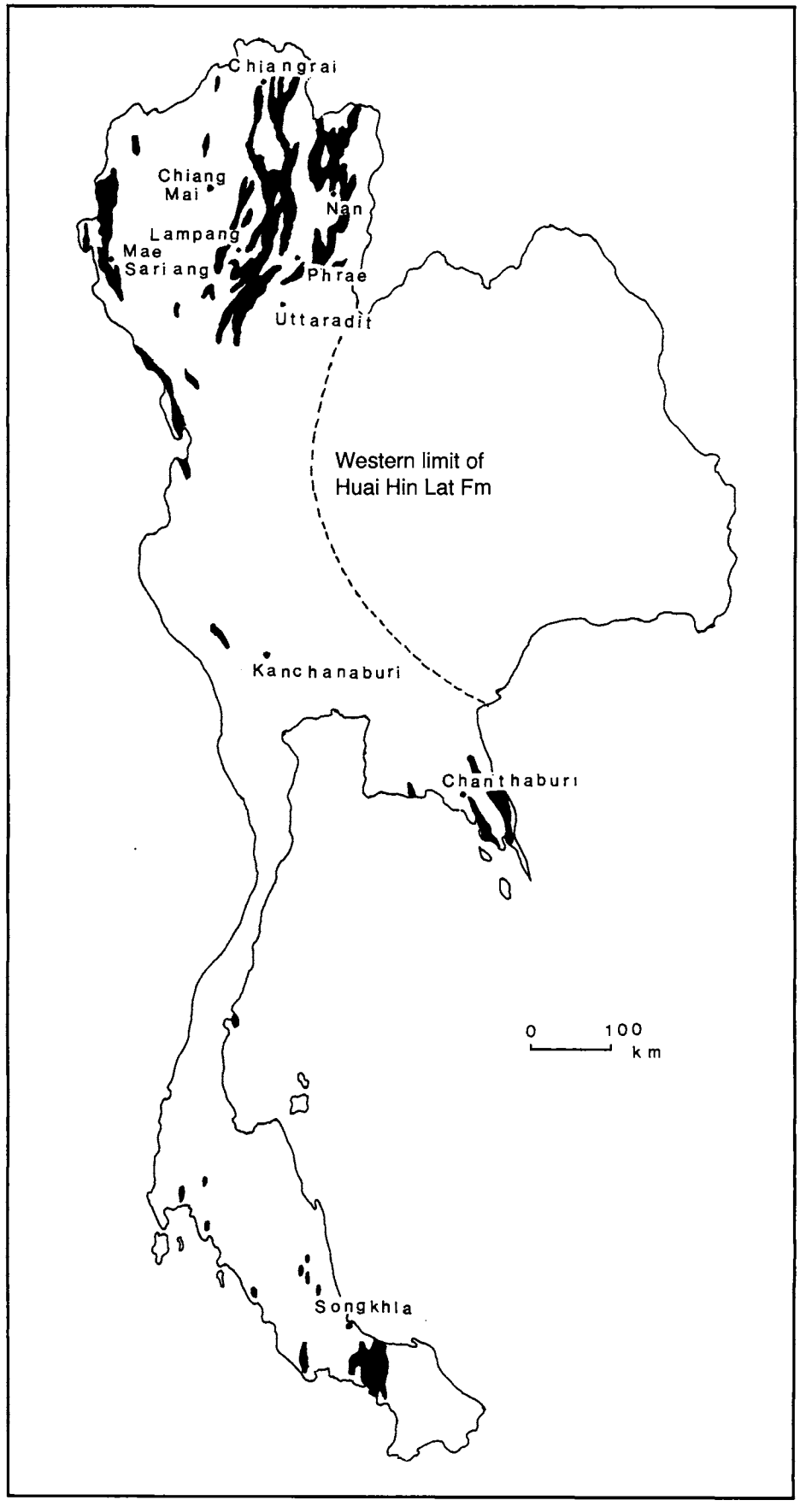

Figure 1. Map showing distribution of Triassic sedimentary sequences in Thailand.

Table 1. Classification and nomenclature of the Triassic stratigraphic units in Thailand.

TERRANE / SYSTEM	Shan - Mergui		Chiang Mai		Sukhothai - Indosinia		
JURASSIC	Upper Mae Moei Gr. Thong Pha Phum Ls.	Kaeng Raboet Fm Chumphon Redbed	Fang Redbed Khao Hin Tang Redbed		Khao Daeng Fm. Phayao Redbed		Nam Phong and Phu Kradung Fms.
TRIASSIC	Lower Mae Moei Gr. Si Sawat Gr.	Mae Sariang Gr.	Phrao Ls. Klaeng Ls.	Laem Ngop Fm	Phrae Gr. / Nam Pat Fm. Lampang Gr.	Pong Nam Ron Fm.	Huai Hin Lat Fm
PERMIAN	Ratburi Gr.		Uthai Thani Ls	Fang Ch	Ngao Gr.	Tha Pla Gr. Sra Kaeo Gr.	Dan Sai Fm. Saraburi Gr.
Oceanic facies							

The continental facies

The Triassic continental facies is widely exposed in northeastern Thailand (The Indosinia) along the edge of the Khorat plateau. But in the subsurface it is overlain by thick Jurassic-Cretaceous Khorat Group in the plateau proper. This facies consists predominantly of siliciclastics deposited in alluvial fan, fluvial and lacustrine environments. It is known as the Huai Hin Lat Formation and is dated paleontologically as the Norian (Chonglakmani and Sattayarak, 1978). It contains typical *Dictyophylum-Clathropteris* flora indicating a warn climate (Kon'no and Asama, 1973). The Kuchinarai Formation which is encountered in the subsurface is considered to be equivalent to the Huai Hin Lat Formation. Elsewhere in other parts of the country minor continental facies is also found intercalated with the marine shelf sediments of the continental platform and marine intra-arc facies.

The continental platform facies

The continental platform facies consists of shallow marine clastics and carbonates but without volcanics. It is deposited in two separate terranes namely the Shan-Mergui and the Chiang Mai.

The Shan-Mergui terrane consists of Lower Mae Moei and Si Sawat Groups exposed extensively in the northwest and west (Braun and Jordan, 1976; Hagen and Kemper, 1976; Kemper *et al.*, 1976). Correlative units in the south are also recorded by Fontaine *et al.* (1993) as the unnamed Triassic limestones in the upper Peninsular and by De Coo and Smith (1975) as the Kodiang Limestone in northwest Malaysia.

The Chiang Mai Terrane consists of sporadic exposure of shelf carbonates belonging to the Phrao Limestone in the north, Klaeng Limestone in the east, and Sabayoi and Khlong Kon Formations in the south (Grant-Mackie *et al.*, 1980; Fontaine and Vachard, 1981; Hahn and Siebenhuner, 1982). The fauna found in these predominant shelf carbonates ranges from Scythian to Early Norian age.

The marine intra-arc facies

The marine intra-arc facies occurs only in the western part of Sukhothai-Indosinia terrane. It consists of the shallow marine siliciclastics and carbonates, the basinal turbidites and the rhyolitic and andesitic volcanics. The sequences are represented by the Lampang (Scythian-Early Carnian), Phrae (Early Norian) and Nam Pat (Early Norian) Groups in the north and the Pong Nam Ron Formation (Early Carnian) in the east. The correlative unit in Malaysia is the Semantan Formation of the Central Belt (Jaafar, 1976).

Prolific invertebrate faunas have been described from the clastics and carbonates of the shelf sediments and turbidites of the intra-arc facies

(Table 2). They include ammonites, bivalves, conodonts, algae, foraminiferas and rare brachiopods. Five ammonite, six bivalve and six conodont zones can be distinguished in these sediments suggesting an Early Induan to an Early Norian age.

The deep marine and oceanic facies

The deep marine and oceanic facies is distributed in two linear belts. One lies discontinuously between the Chiang Mai and Sukhothai-Indosinia terranes. It originates in Chiangrai forming isolated remnants of pelagic overthrust sheets of Fang Chert lying on the shallow marine carbonates and siliciclastics of the Chiang Mai terrane. It ranges in age from the Devonian to Middle Triassic (Jaeger *et al.*, 1969; Caridroit, 1993; Sashida *et al.*, 1993). This belt extends southward and is exposed at Chantaburi where pillow basalt is found associated with Middle Triassic radiolarian chert of the Laem Ngop Formation (Hada *et al.*, 1997). The long period of the oceanic realm is also assumed as Carboniferous radiolarian chert is also recorded in this area (Salyapongse, 1992).

The other belt is well-exposed in Mae Sariang (Mae Sariang Group) and extended southward to Tak, Mae Sot, Kanchanaburi and Songkhla (Na Thawi Formation). This facies consists mainly of radiolarian chert, pelagic limestones and turbidites (Caridroit *et al.*, 1993; Chonglakmani and Grant-Makie, 1993; Tofke *et al.*, 1993). It can be correlated with the Semanggol Formation of the Kulim-Taiping zone in northwest Malaysia. An equivalent facies consisting of chert, metaargillite, red shale, limestone and deepwater rhythmite is also recorded in central Sumatra (Eubank and Makki, 1981).

IMPLICATION ON GEOTECTONIC EVOLUTION

The synthesis of the geologic history of Thailand and its neighbouring countries reveals that this region of Southeast Asia is a complex orogenic collage. Earlier terrane accretions are in the pre-Late Carboniferous forming the stable mass or Indosinia which includes northeastern Thailand. Subsequent accretion is in the Late Permian which welded Sukhothai terrane to the Indosinia along the well-known Nan-Uttaradit–Sra Kaeo suture (Fig. 2).

The distribution of the Permian and Triassic sequences and its related volcanics and plutonics shows that the major terrane accretions in Thailand are in the Late Triassic (Figs. 2 and 3). Two stages of the Late Triassic accretions can be distinguished in this study.

First stage of the Late Triassic ocean closure

The first stage of the Late Triassic ocean closure involves the accretion of the Chiang Mai and amalgamated Sukhothai-Indosinia terranes. The western part of the Sukhothai-Indosinia terrane is a volcanoplutonic setting characterised by I-type granites and its related rhyolitic and andesitic volcanics. The Lampang and Phrae Groups ranging in age from Scythian to Early Norian are deposited in the marine intra-arc basins. Correlative units of the same tectonic setting are also recorded in eastern Thailand (Pong Nam Ron Formation) and in Central Belt of Malaysia (Semantan Formation). The Huai Hin Lat and the Kuchinarai Formations are the continental sediments deposited in the retroarc foreland basins in northeastern Thailand.

The corresponding deep marine and oceanic realm is represented by the Fang Chert and the Laem Ngop Formation forming a belt in between the Chiang Mai and the Sukhothai-Indosinia terranes. This belt corresponds to the boundary of the Triassic S-type granites on the Chiang Mai and the Triassic I-type granites on the Sukhothai-Indosinia terranes.

It is evident from the distributions of the Triassic sequences and its tectonic setting that the polarity of the subduction is to the east underneath the Sukhothai Indosinia terrane. This is in agreement with the polarity of the Bentong-Raub suture in Malaysia (Hutchison, 1989). The northward extension of this suture is the Changning-Menglion belt of Yunnan. The Early, Middle and Late Triassic sediments are represented by ammonites, bivalves and conodonts. Reassessment of the age of the Phrae Group in northern Thailand indicates that its basal part is the earliest Norian based on the occurrence of *Halobia styriaca* Mojs. The main part of the Carnian appears to be absent except the Early Carnian represented by the upper part of the underlying Lampang Group. The Late Carnian is considered to be the time of tectonic movement caused by accretion of the Chiang Mai and Sukhothai Indosinia terranes. This interpretation is supported by the absence of the Late Triassic radiolaria or other deep water fauna in the Fang Chert and the Laem Ngop Formation.

Second stage of the Late Triassic ocean closure

The second stage involves the accretion of the shan-Mergui and amalgamated Chiang Mai-Sukhothai-Indosinia terranes. No volcanoplutonic complex is recognized as it is likely to be removed by complex thrusting and erosion. The deep marine

Table 2. Biostratigraphic classification of the marine Triassic sequences.

	Ammonite Zone	Continental facies		Shelf and Terbidite facies						Oceanic facies	
					Ammonite zone	Bivalve zone	Foraminifera, Algae, Conodont				Pelagic Bivalve, Radiolaria, Conodont
JUR.											
RHAET	Crickmayi										
NORIAN	Amoenum							SI SAWAT GROUP			
	Cordilleranus										
	Columbianus										
	Rutherfordi	HUAI HIN LAT FM	Dictyophyllum-Clathropteris flora	PHRAE							
	Magnus				Anatomites	Halobia fallax Halobia charlyana Halobia styriaca	Epigondolella abneptis		Involutina, Bouenia Epigondolella abneptis		
	Dawsoni										Halobia styriaca
	Kerri										
CARNIAN	Macrolobatus									MAE SARIANG	
	Welleri										Epigondolella nodosa
	Dilleri										
	Obseum				Paratrachyceras	Daonella					
	Desatoyense										Gondolella polygnathiformis
LADINIAN	Sutherlandi						Gondolella polygnathiformis				
	Maclearni					Daonella indica					
	Meginae						Neogondolella acuta				
	Poseidon										
ANISIAN	Chischa				Balatonites					LAEM NGOP	Rodiolarian chert
	Deleeni			LAMPANG GROUP					Neogondollela monbergensis Neospathodus timorensis		
	Caurus				Leiophyllites						
	Mulleri										
OLENEKIAN	Subroustus										
	Pilaticus										
	Tardus										
	Romunderi						Neospathodus pakistanensis				
INDUAN	Sverdrupi									FANG	
	Candidus										
	Strigatus				Ohpiceras	Claraia					Radiolarian chert Parentactinia nakatsugawaensis
	Commune										
	Boreale										
	Concavum										

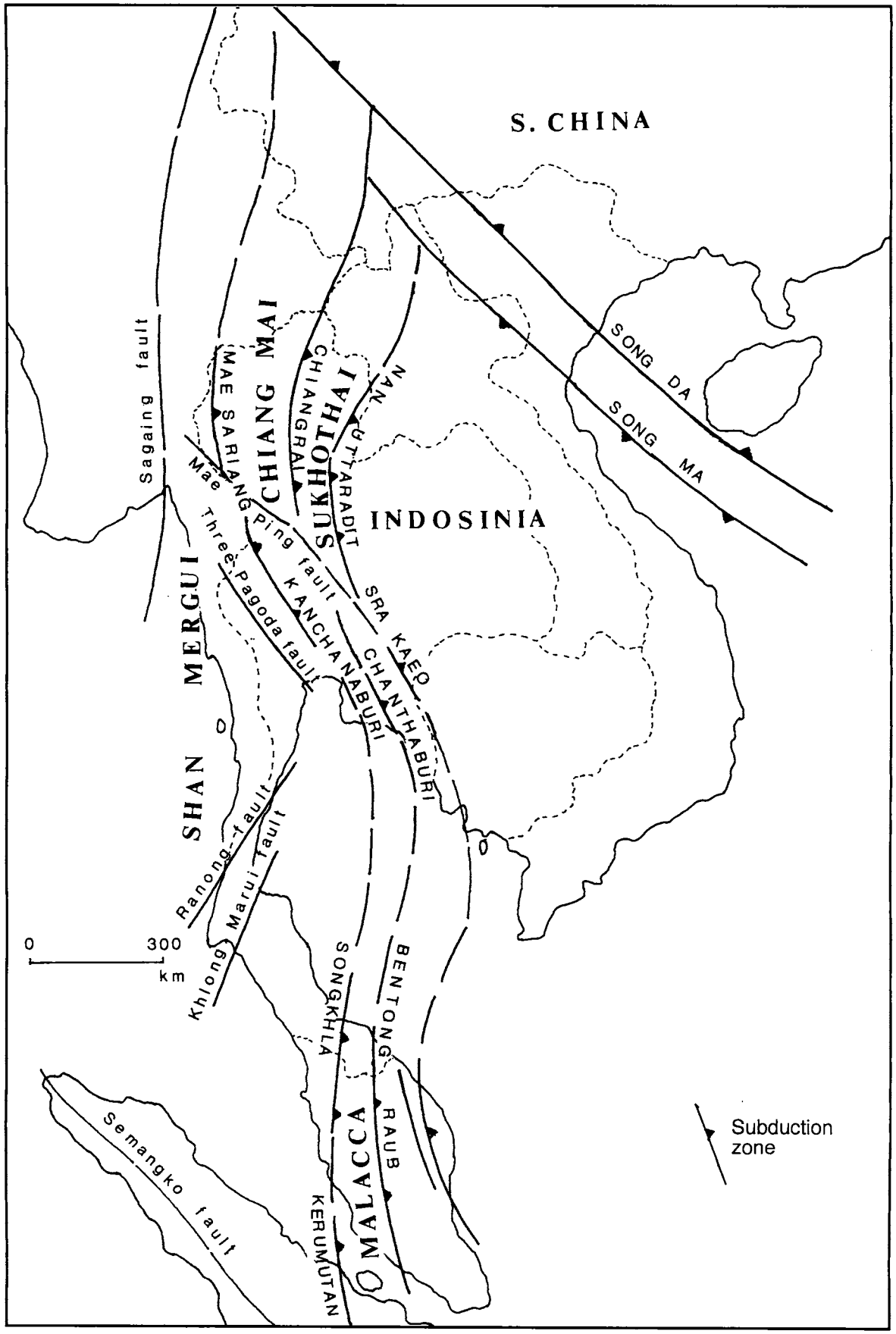

Figure 2. Map showing major tectonic elements.

and oceanic facies (Mae Sariang Group and its correlative units) can be delineated between these two terranes.

The Semanggol Formation of northwest Malaysia can be correlated with the Mae Sariang Group suggesting the continuation of this oceanic belt. In central Sumatra, an equivalent fancies of deepwater and oceanic sediments is bounded on the east by the Kerumutan suture representing the eastward subduction of the Mergui Platelet underneath the Malacca Platelet (Aspen *et al.*, 1982). So the Mae Sariang suture extends southward to join the Songkhla-Kerumutan line. In Thailand this oceanic facies and its related suture have been displaced by several younger linear fractures, e.g. the Mae Ping, the Three Pagoda, the Ranong, the Khlong Marui etc.

This deep marine and oceanic belt contains typical Early Norian fauna which is not recorded in the eastern oceanic belt discussed earlier. The closing of the Mae Sariang-Songkhla ocean is therefore later than the Chiangrai-Chanthaburi ocean and is considered to be in the Middle to Late Norian.

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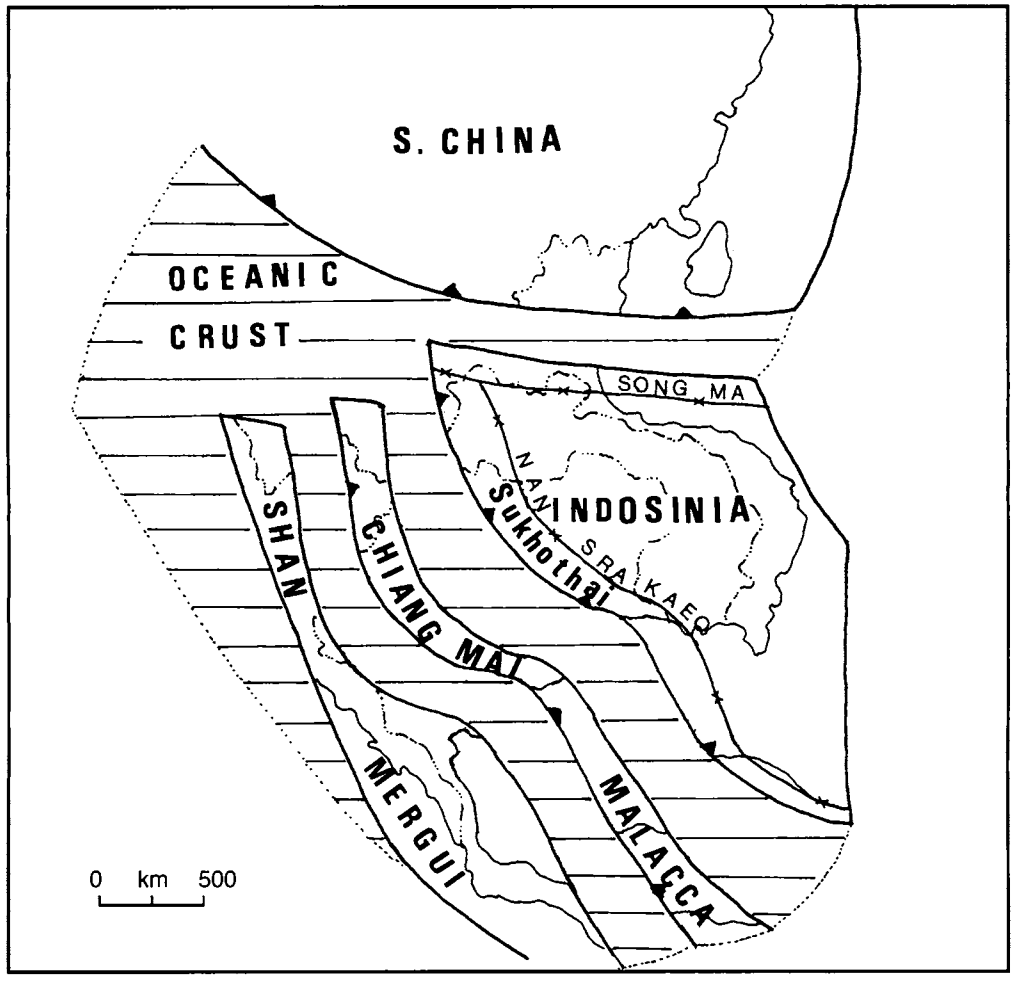

Figure 3. Map showing plate reconstruction in the Early Triassic.

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